



**XII**

**CONGRESSO**

**CONGRESO**

**IBÉRICO DE GEOQUÍMICA**

**Extended Abstracts**

22 - 26 Setembro de 2019  
Septiembre

Évora, Portugal

## **Elementos traço característicos das unidades detríticas Paleozoicas da Zona de Ossa-Morena (Portugal): constrangimentos geodinâmicos**

### ***Trace element features of Palaeozoic detrital units of the Ossa-Morena Zone (Portugal): geodynamic constraints***

**Roseiro, J.<sup>1\*</sup>, Moreira, N.<sup>1</sup>, Nogueira, P.<sup>1</sup>, Maia, M.<sup>1</sup>, Araújo, A.<sup>1</sup>, Pedro, J.<sup>1</sup>**

<sup>1</sup> Institute of Earth Sciences (ICT), Évora Pole; CLAV, Rua Romão Ramalho 59, 7000-671 Évora

\* ze.roseiro45@gmail.com

**Resumo:** O quimismo dos metassedimentos correspondentes às diferentes unidades litoestratigráficas detríticas do Paleozoico (Câmbrico a Devónico) do sector português da Zona de Ossa-Morena regista particularidades geoquímicas características do seu ambiente deposicional, o que permite tirar ilações relativas à evolução geodinâmica do Terreno Autóctone Ibérico durante o Ciclo Varisco. As relações entre vários elementos traço (essencialmente Nb/Ta, Zr/Hf, Th/U, La/Th-Sc e padrões normalizados de ETR) nas sucessões detríticas revelam que as diferentes formações derivam maioritariamente de uma fonte ácida continental, embora com particularidades que sugerem misturas com outras componentes sedimentares. As amostras representativas das unidades do Câmbrico, Ordovícico e Silúrico apresentam influências significativas de sedimentos típicos de margem continental passiva, enquanto as amostras do Devónico aparentam contribuições de arco oceânico com maior componente básica, o que poderá indicar uma transição do ambiente tectónico durante a sua deposição, ou seja, durante o Devónico inferior.

Assim, as formações Variscas ante-Devónicas podem ser interpretadas como resultantes da sedimentação derivada do desmantelamento progressivo de um soco continental (arco Cadomiano e terrenos Gondwanicos) em bacias geradas durante o episódio de estiramento crustal ocorrido durante o Câmbrico. Por outro lado, as unidades do Devónico Inferior podem corresponder a rochas metassedimentares resultantes do desmantelamento de um arco vulcânico (básico a intermédio), revelando a presença de uma margem ativa no SW da Zona de Ossa-Morena durante este período.

**Palavras-chave:** Litogeoquímica; Proveniência Siliciclástica; Unidades Detríticas; Zona de Ossa-Morena

**Abstract:** Chemical features regarding the different detrital lithostratigraphic Palaeozoic (Cambrian – Devonian) units from the Portuguese sector of the Ossa-Morena Zone regist geochemical aspects typical of their depositional environment, which allow inferences on the geodynamic evolution of the Iberian Autochthonous Terrain during the Variscan Cycle. Trace elements relationships (essentially Nb/Ta, Zr/Hf, Th/U, La/Th-Sc and REE chondrite-normalized patterns) of the detrital succession reveal that the different formations derive mostly from an acid continental source, though with features that suggest mixed sedimentary components. Cambrian, Ordovician and Silurian representative samples show significant influences typical of passive margin sediments, while Devonian samples appear to have an oceanic arc contribution, with an increase in basic components, which may indicate a transition on the tectonic environment, during their deposition.

Ante-Devonian Variscan formations are therefore interpreted as representing debris deposition, derived from the progressive dismantling of a continental basement (Cadomian arc and Gondwana terranes), in sedimentary basins formed during the lower Cambrian crustal thinning episode. Contrastingly, Devonian units correspond to metasedimentary rocks derived from a dismembered (basic-intermediate) volcanic arc, revealing an active margin in the SW Ossa-Morena Zone during this period.

**Keywords:** Lithogeochemistry; Siliciclastic Provenance; Detrital Units; Ossa-Morena Zone

## 1. Introduction

Trace element geochemical data of detrital rocks may be a relevant tool to study the depositional environment, sedimentary sources and tectonic setting of siliciclastic units. Such methodologic approach is feasible because some trace elements do not tend to fractionate during physical and chemical weathering, mineral sorting during transport and diagenesis or regional metamorphism.

In the Ossa-Morena Zone (OMZ, SW Iberia), several metasedimentary and metavolcanic rock suites are defined and distinguished based on bio- and lithostratigraphic correlations, structural features, zircon geochronological data and metavolcanic rocks lithogeochemistry (e.g. Robardet & Gutierrez Marco, 2004; Pereira et al., 2006; Sanchez Garcia et al., 2010; Araújo et al., 2013). However, geochemical data for the OMZ metasedimentary rocks are scarce.

In this study we verify if trace element geochemistry of the OMZ siliciclastic units corroborate previous geological and geochemical data on tectonic setting, and also we assess their provenance, consequently contributing to the knowledge of the geodynamic evolution of the OMZ and Iberian Variscides.

### 1.1. Geological Setting

The lower-middle Palaeozoic detrital suites of the OMZ consist in a succession of low-grade metasedimentary rocks, discordantly settled on top of the 'Série Negra' Neoproterozoic basement (Oliveira et al., 1991; Araújo et al., 2013, and references therein).

Structural and stratigraphic studies distinguished several lithostratigraphic formations in the Portuguese tectono-stratigraphic sectors of the OMZ, which can be organized in a simplified OMZ lithostratigraphic succession, as represented in Fig. 1.

## 2. Methods

Fifteen OMZ metasedimentary rock samples, representing the Carvalho, Barrancos, Colorada, *Xistos com Nódulos* and Terena formations (ages ranging from Cambrian to Lower Devonian), were collected and trace element analyses were carried out in ALS laboratories (Sevilla). This new data was compared and assembled with published data from the Vila Boim, Terrugem, Carvalho, Colorada, *Xistos Raiados* and Terena formations (n = 56; Pereira et al., 2006; Borrego, 2009; Cruz, 2013).

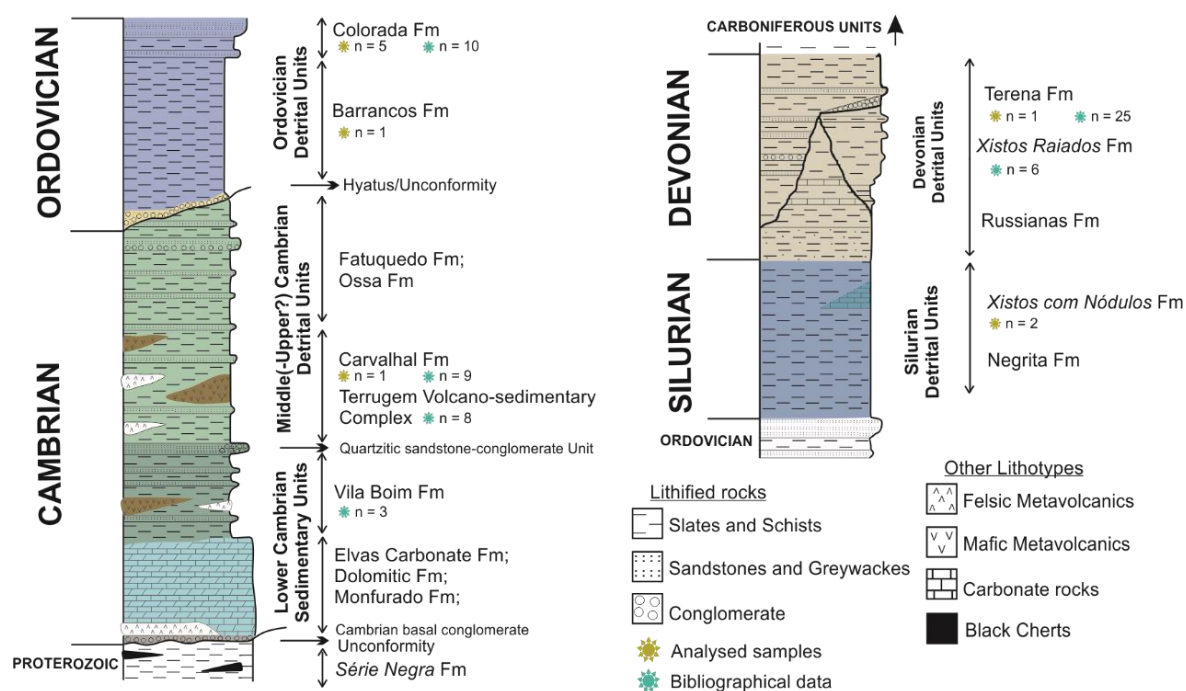


Fig. 1 – Simplified Ossa-Morena Zone lithostratigraphic column of the Cambrian – Devonian (meta)sedimentary sequences (adapted from Oliveira et al., 1991; Araújo et al., 2013).

Range values for analyses of most relevant components presented at Table 1.

Tab. 1 – Value range of analyses for the different Ossa-Morena Zone detrital units. Obtained data assembled with bibliographical data from cited references.

	Cambrian		Ordovician	Silurian	Devonian
	lower(n = 3) min. max.	middle-upper?(n = 18) min. max.	(n = 16) min. max.	(n = 2) min. max.	(n = 32) min. max.
Ba	21 - 295	45 - 1256	105 - 2494	46 - 1115	17 - 1285
Sr	58 - 111	30 - 165	12 - 157	15 - 270	10 - 273
Rb	2 - 149	3 - 246	14 - 282	9 - 271	2 - 249
V	52 - 121	35 - 273	19 - 1220	225 - 360	39 - 287
Cr	90 - 280	30 - 160	30 - 230	30 - 160	30 - 150
Zr	157 - 192	81 - 508	142 - 530	17 - 246	127 - 858
Hf	4 - 4	2 - 13	4 - 13	0 - 8	3 - 21
Nb	7 - 14	2 - 23	3 - 29	1 - 31	5 - 26
Ta	1 - 1	0 - 2	0 - 2	0 - 2	0 - 3
Th	5 - 12	0 - 22	4 - 27	0 - 25	3 - 23
U	1 - 3	0 - 4	1 - 11	2 - 3	1 - 6
Y	18 - 27	17 - 47	10 - 75	6 - 58	13 - 43
Sc	6 - 19	4 - 43	2 - 30	2 - 22	3 - 26
La	15 - 42	3 - 74	15 - 77	3 - 87	14 - 77
Ce	32 - 88	9 - 148	34 - 159	4 - 167	30 - 154
Sm	3 - 7	3 - 11	3 - 14	1 - 13	3 - 13
Eu	1 - 2	1 - 2	1 - 3	0 - 2	1 - 3
Gd	3 - 6	3 - 9	2 - 12	1 - 11	2 - 9
Yb	2 - 3	2 - 4	1 - 6	1 - 5	1 - 5

### 3. Geochemical Features

Geochemical data here reported are given in *average  $\pm$  standard deviation* or ranging *minimum – maximum*.

Lower Cambrian rocks show slightly low Nb/Ta ratios ( $14.5 \pm 0.9$ ), but high Zr/Hf ( $40.3 \pm 3.8$ ), and Th/U =  $4.75 \pm 0.3$ , whereas Middle (to Upper?) Cambrian units display average lower Nb/Ta ( $13.3 \pm 2.5$ ) and Zr/Hf ( $37.8 \pm 1.8$ ) ratios, but similar Th/U ( $4.49 \pm 1.6$ ) contents. All Cambrian rocks have similar chondrite-normalized (CN) REE patterns:  $[\text{La}/\text{Sm}]_{\text{CN}} = 3.0 - 4.3$ ,  $[\text{La}/\text{Yb}]_{\text{CN}} = 6.1 - 14.2$ ,  $[\text{Eu}/\text{Eu}^*]_{\text{CN}} = 0.55 - 1.0$  and  $[\text{Ce}/\text{Ce}^*]_{\text{CN}} = 0.8 - 1.0$ . Analyses for Ordovician and Silurian samples display chemical features similar to those described in Cambrian successions. Ordovician units show slightly lower Nb/Ta ( $13.6 \pm 1.8$ ), Zr/Hf ( $37.6 \pm 4.1$ ) and Th/U ( $3.6 \pm 1.4$ ) ratios, and comparable REE patterns, with  $[\text{La}/\text{Sm}]_{\text{CN}} = 2.3 - 4.5$ ,  $[\text{La}/\text{Yb}]_{\text{CN}} = 6.2 - 12.9$ ,  $[\text{Eu}/\text{Eu}^*]_{\text{CN}} = 0.6 - 0.8$ , and  $[\text{Ce}/\text{Ce}^*]_{\text{CN}} = 0.9 - 1.2$ . Silurian units exhibit average Nb/Ta =  $13.3$ , Zr/Hf =  $32 - 56$ , Th/U =  $0.3 - 9.1$ , and REE patterns with  $[\text{La}/\text{Sm}]_{\text{CN}} = 2.5 - 4.1$ ,  $[\text{La}/\text{Yb}]_{\text{CN}} = 3.2 - 11.1$ ,  $[\text{Eu}/\text{Eu}^*]_{\text{CN}} = 0.5 - 0.6$ , and  $[\text{Ce}/\text{Ce}^*]_{\text{CN}} = 0.7 - 1.0$ .

The Lower Devonian successions display distinct trace element features, with significantly lower ratios: Nb/Ta =  $11.7 \pm 1.2$ , Zr/Hf =  $38.5 \pm 3.0$ , Th/U =  $4.3 \pm 1.8$ ,

and REE patterns with  $[\text{La}/\text{Sm}]_{\text{CN}} = 2.6 - 4.5$ ,  $[\text{La}/\text{Yb}]_{\text{CN}} = 4.9 - 13.2$ ,  $[\text{Eu}/\text{Eu}^*]_{\text{CN}} = 0.7 - 1$ , and  $[\text{Ce}/\text{Ce}^*]_{\text{CN}} = 0.9 - 1.1$ .

### 5. Provenance and Geodynamic Evolution

The trace element geochemical data here presented allows some deductions on the provenance and, wherefore, the geodynamic evolution of the OMZ metasedimentary rock suites. La, Th, Hf and Sc contents, discriminatory diagrams (Fig. 2) and REE CN patterns enables to assign the studied samples to their likely depositional environment: i) metasedimentary successions with ages ranging from Cambrian to Silurian are apparently derived from an acid continental source (continental margin – continental island arc?), showing passive margin chemical affinities with ancient sediments (increasing resistate minerals component, presumably zircon, or/and a coarser debris component; Floyd & Leveridge, 1987), while ii) Lower Devonian detrital rocks chemistry suggests a mixed acid/basic source contribution (volcanic arc component?).

### 6. Geodynamic Considerations

The provenance of Cambrian-Silurian sediments can be attributed to the progressive dismemberment of a continental basement, coming from the northern rim of Gondwana (which includes the Cadomian arc; Pereira et al., 2006; Dias et al., 2016) while the Lower Devonian units suggest a transitional deposition environment, from a passive margin to an active tectonic setting. New geochemical data regarding OMZ Palaeozoic detrital units supports and agrees with previous works (e.g. Borrego et al., 2006; Ribeiro et al., 2010; Moreira et al., 2014; Moreira & Machado, 2019), supporting geodynamic models, that proposed subduction initiation in SW Iberian Variscides during Lower Devonian ages. Nonetheless, a thoroughly study is needed, regarding major element geochemistry, and correlation with other formations not included in this work, namely in the Spanish sectors of OMZ and other Variscan terranes.

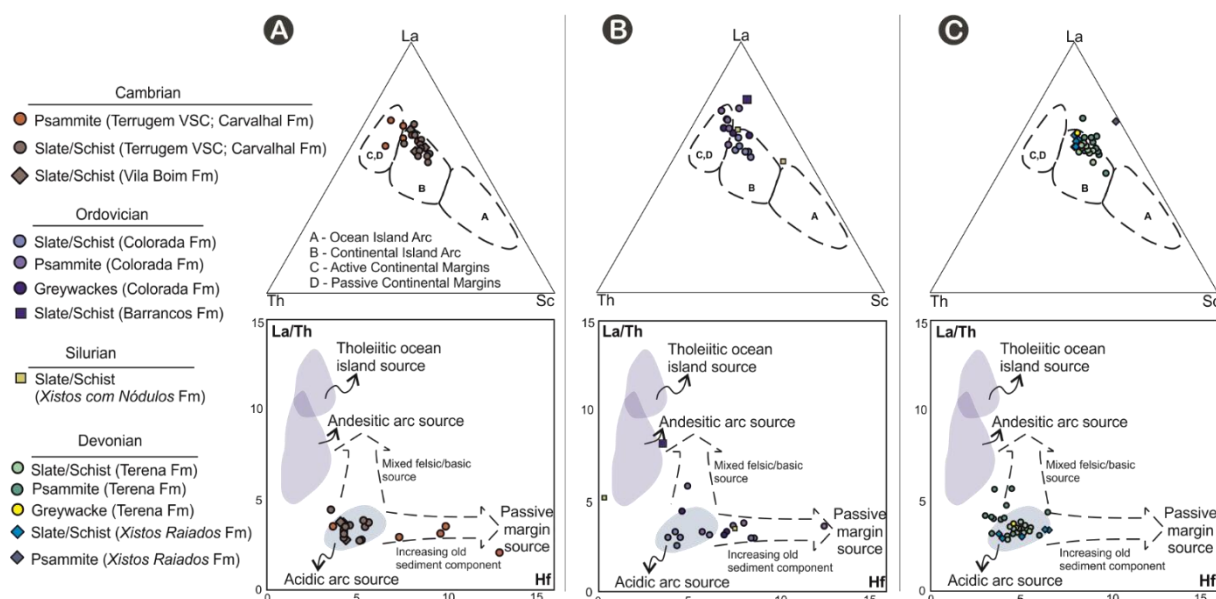


Fig. 2 – Discrimination tectonic diagrams for the different OMZ (A) Cambrian, (B) Ordovician-Silurian and (C) Devonian metasedimentary units. Ternary La-Th-Sc diagram from Bhatia & Crook (1986) and La/Th-Hf diagram from Floyd & Leveridge (1987)

## Acknowledgments

This work is a contribution to the project ZOM3D: ALT20-03-0145-FEDER-000028, funded by Alentejo 2020 through the FEDER/FSE/FEEI. The authors also acknowledge the funding provided to Institute of Earth Sciences through the contracts UID/GEO/04683/2013 with FCT and COMPETE POCI-01-0145-FEDER-007690.

## References

- Araújo, A., Piçarra de Almeida, J., Borrego, J., et al., 2013. As regiões central e sul da Zona de Ossa-Morena. In: R. Dias et al. (Eds), *Geologia de Portugal*, Volume 1, Escolar Editora, 509-549.
- Bhatia, M.R., & Crook, K.A., 1986. Trace element characteristics of graywackes and tectonic setting discrimination of sedimentary basins. *Contributions to Mineralogy and Petrology*, 92(2), 181-193.
- Borrego, J., 2009. Cartografia geológico-estrutural de um sector da zona de Ossa-Morena subsector de Estremoz-Barrancos-Ficalho e sua interpretação tectónica. Tese de Doutoramento Universidade de Évora, 479p.
- Borrego, J., Araújo, A., Fonseca, P. & Ribeiro, M.A., 2006. Estudos de proveniência em litologias detríticas do Sinclinal de Terena (ZOM): tectónica e evolução geodinâmica durante o Silúrico e o Devónico inferior. VII Congresso Nacional de Geologia, Estremoz, 53-56.
- Cruz, C., 2013. Efeitos metamórficos e fluidos do Complexo Plutónico de Santa Eulália. Tese de Mestrado Universidade do Porto, 92p.
- Dias, R., Ribeiro, A., Romão, J., et al. 2016. A review of the Arcuate Structures in the Iberian Variscides; Constraints and Genetic Models. *Tectonophysics*, 681C, 170-194.
- Floyd, P.A., & Leveridge, B.E., 1987. Tectonic environment of the Devonian Gramscatho basin, south Cornwall: framework mode and geochemical evidence from turbiditic sandstones. *Journal of the Geological Society*, London, 144(4), 531-542.
- Moreira, N., Araújo, A., Pedro, J. & Dias, R., 2014. Evolução Geodinâmica na Zona de Ossa-Morena no contexto do SW Ibérico durante o Ciclo Varisco. *Comunicações Geológicas*, 101(1), 275-278.
- Moreira, N., Machado, G., 2019, Devonian sedimentation in Western Ossa-Morena Zone and its geodynamic significance. In: Quesada, C., Oliveira, J.T. (Eds.), *The Geology of Iberia: a geodynamic approach. Vol.2: The Variscan Cycle*. Springer (Berlin), Regional Geology Series, 364-372.
- Oliveira, J.T., Oliveira, V. & Piçarra, J.M., 1991. Traços gerais da evolução tectono-estratigráfica da Zona de Ossa-Morena. *Cadernos do Laboratorio Xeológico de Laxe*, 16, 221-250.
- Pereira, M.F., Chichorro, M., Linnemann, U., et al., 2006. Inherited arc signature in Ediacaran and Early Cambrian basins of the Ossa-Morena zone (Iberian Massif, Portugal): paleogeographic link with European and North African Cadomian correlatives. *Precambrian Research*, 144(3-4), 297-315.
- Ribeiro, A., Munhá, J., Fonseca P.E, et al., 2010. Variscan ophiolite belts in the Ossa-Morena Zone (Southwest Iberia): Geological characterization and geodynamic significance. *Gondwana Research*, 17, 408-421.
- Robardet, M. & Gutiérrez-Marco, J.C., 2004. The Ordovician, Silurian and Devonian sedimentary rocks of the Ossa-Morena Zone (SW Iberian Peninsula, Spain). *Journal of Iberian Geology*, 30, 73-92.
- Sanchez-Garcia, T., Bellido, F., Pereira, M.F., et al., 2010. Rift-related volcanism predating the birth of the Rheic Ocean (Ossa-Morena zone, SW Iberia). *Gondwana Research*, 17(2), 392-407.